Method for Calculating Warehousing Costs Based on Simulation Results

Bálint Hirkó, Zoltán András Nagy, Csaba Tápler

Department of Logistics and Forwarding, Széchenyi István University
H-9026, Győr, Egyetem tér 1. Hungary
hirko@sze.hu, nagyz@sze.hu, tapler@sze.hu

Abstract: The warehousing costs are a significant part of the supply chains costs. This article shows the connections between the warehousing costs and the client number of a 3PL. The parameters are based on paragon simulation. The simulation results are inserted into transportation cost function, which improves the whole model.

Keywords: SMC, 3PL, model, warehouse

1. Introduction

This paper demonstrates how to use vehicle routing software's in warehouse simulation, and how we can use the simulation results to calculate warehouse costs.

The main point of warehouse simulation is to create the computerized representation of the warehouse, by introducing some assumptions, estimations and simplifications. After the model is created, scenarios should be built up - by altering different parameters of the model- to simulate real life processes in the warehouse; e.g.: increase of vehicle or forklift number. By evaluating the results we gain that information which would be expensive or impossible in case of the examination of the real system.

The common vehicle routing software's are rarely used for warehouse material handling simulation, although all algorithms needed for modeling processes are built in many of them. All the road transportation elements used in vehicle routing applications can be converted to a warehouse system element in theory, the algorithms are the same.

2. Warehouse simulation with vehicle routing software

The aim is to simulate the total distance and productive time taken by forklifts in a warehouse. With the help of these data we can calculate the total warehouse costs.

The method of building up the simulation is basically the same as in case of vehicle routing simulation. At first the master data has to be collected (all possible system elements), after that different scenarios can be built up by using these system elements.

The benefits of vehicle routing simulation are the following:

- Reduce transport costs
- Improve customer service
- Maintain efficiency of transport resources during execution
- Increase control of transport - better management reporting
- Reduce delivery lead times
- Support strategic decision making

The benefits of warehouse simulation are the following:

- With the help of simulation we can forecast the resource need of future warehouse processes
- With the help of simulation we can forecast the cost of future warehouse material handling

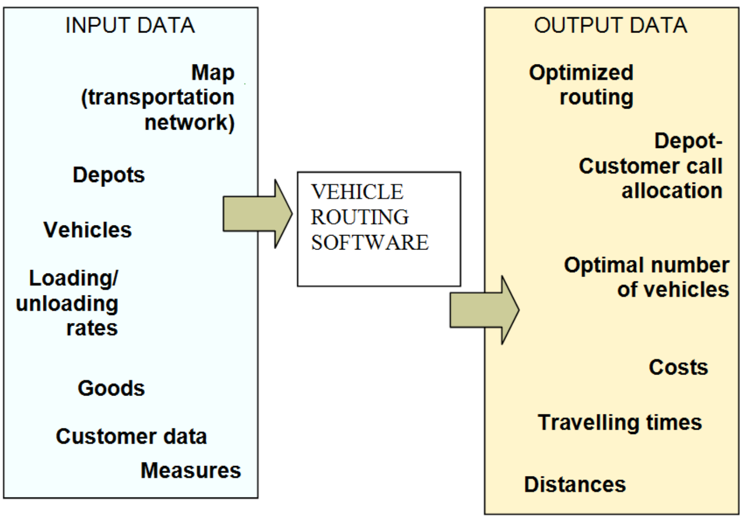

Figure 1. Schematic system model of vehicle routing softwares

Figure 1 demonstrates routes schematic system model of vehicle routing softwares. By creating orthogonal routs on the transportation map, a warehouse corridor network can be built up. On this orthogonal network, nodes for the warehouse rack locations should be placed. Attributes of network segments are average velocity and length.

Warehouse material handling areas can be converted to depots of routing software.

Let us assume that only pallets are stored in racks, forklifts transport them to the consolidation area, where unit pallets are made. Attributes of consolidation area are the time windows, loading and unloading rates. Depending on the direction of material flow, this area will be the loading/unloading point.

Vehicle master data contains the data of forklifts, which are the followings: vehicle capacity, fix and variable costs (based on running performance or elapsed time).

The unit of transported goods is pallet, since the forklifts collect and spread whole pallets to and from the racks – this way vehicle capacity is one pallet.

Customer master data contains the position and loading rates of the rack locations. Locations on upper levels have higher loading/unloading rates, since lifting goods needs extra time. As many "customers" should be declared at the nodes of the route network as many locations are served from that node.

Customer order data are the items of the picking list, it contains the order quantity (1 pallet/rack) and loading/unloading rate (higher levels). For warehouse simulation no time-windows should be determined, but we have to declare whether the order is a supply or demand point.

Loading and unloading times have both fix and variable – time dependent – components.

The measure can be weight, volume – in this case the measure is pallet. Most routing softwares can not handle lengths below 1m; it is suggested to use at least 10 times magnification for warehouse simulation. (In this case variable costs should be decreased, and average velocity should be increased ten times).

Figure 2 shows the graphical visualization of a warehouse simulation model.

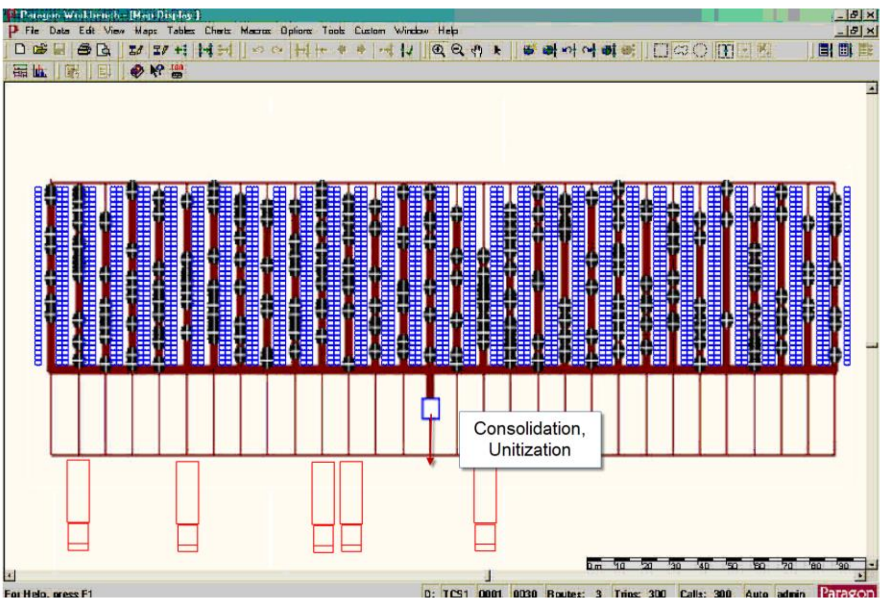

Figure 2. Warehouse simulation model

By running the simulation the routes of forklifts, the total distance covered, the time of single routes, the necessary number of vehicle, capacity data, and other representative data will be generated.

3. Simplifications in the model

To model warehouse processes we have to declare some simplifications. In our case we assume that one corridor belongs to one client. The picking points are evenly distributed.

We assume that the material handling costs increase parallel with the increase of the warehouse length (this way also with the number of clients).

During the simulation we have examined one hour long periods. The cost results for one shift are gained after simulation cost results multiplied by 8 hours.

In this case main point of simulation is to get data about the distance and taken during material handling.

4. Calculation of warehouse costs based on simulation results

The total warehouse costs are built up from three factors:

$$\Sigma K_{WH} = K_{fix}^{WH} + K_{fix}^{FL} + K_{v}^{D} \tag{1}$$

Where:

K_{fix}^{WH}: Fix costs of warehouse (EUR)

K_{fix}^{FL}: Fix costs of forklifts and forklift operators $\left(\frac{\text{EUR}}{\text{Forklifts}}\right)$

K_{v}^{D}: Distance dependent costs (EUR)

K_{fix}^{WH} is not a constant value, it is the function of the length of the warehouse (which depends on the number of clients).

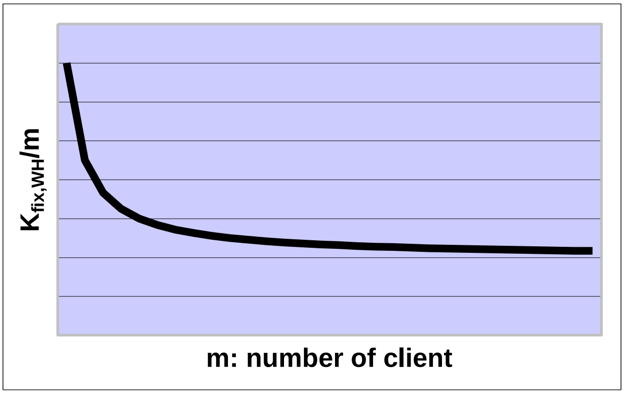

Figure 3. Warehouse fix costs in the function of the number of clients

The costs of forklifts K_{fix}^{FL} depends on the number of the forklifts, it contains the wage of the forklift operator, the amortization and leasing price of the forklifts. It can be expressed as follows:

$$K_{fix}^{FL} = n_{FL} \cdot k_{fix}^{FL} \qquad (2)$$

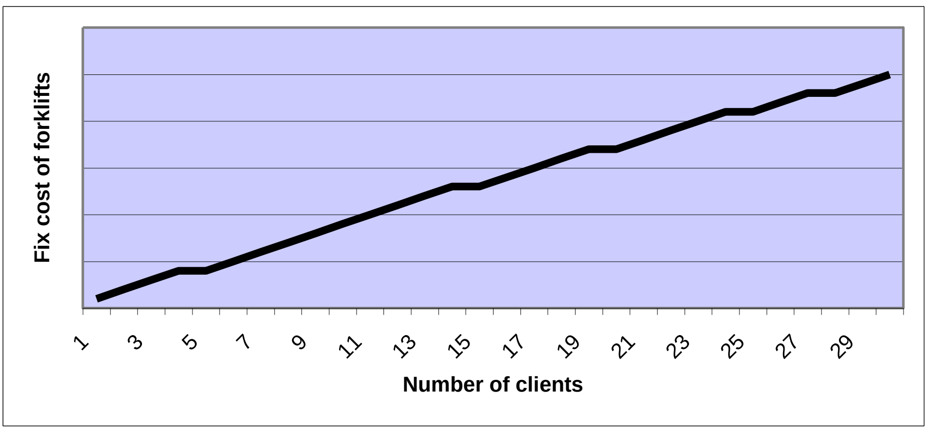

Figure 4. Example of fix cost of forklifts in the function of the client number

By simulation we have gained information about the covered distance during one hour long periods, so the total distance taken in one shift is the gained results multiplied by the number of hours in a shift. – We assumed that the needs are constant during the whole shift.

Number of forklifts:

$$n_{FL} = \left(\frac{t_{pr}}{60} + 0{,}99 \right)_{INT} \tag{3}$$

Where:

t_{PR} : Total productive time of picking process, value is gained from simulation

And the total productive time can be calculated

$$t_{pr} = \frac{D}{\bar{v}} \tag{4}$$

Let us put (4) into (3):

$$n_{FL} = \left(\frac{D}{\bar{v} \cdot 60} + 0{,}99 \right)_{INT} \tag{5}$$

The distance dependent variable cost can be expressed as in the following equation.

$$K_v^D = D \cdot k_D \tag{6}$$

Where:

D: Total distance covered by whole material handling process

k_D : Distance dependent variable cost of forklifts

The covered distance data is gained by warehouse simulation. As we increased the number of clients the distance also increased, shown on Figure 3.

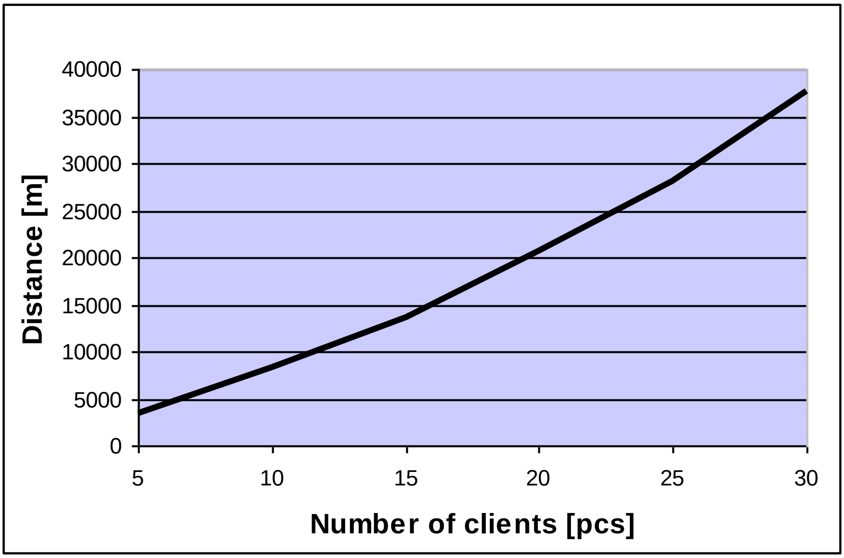

Figure 5. Distance taken during material handling in one hour in function of the number of clients

A correlation between the client number and the distance can be expressed with the help of polynomial iteration method:

$$D(m) = d_0(60 + 10m + m^2) \tag{7}$$

The characteristic shown above is only valid in case of the parameters of the warehouse in our model, where $d_0 = 30m$.

Figure 4 shows the calculated and the simulated distance of warehouse material handling.

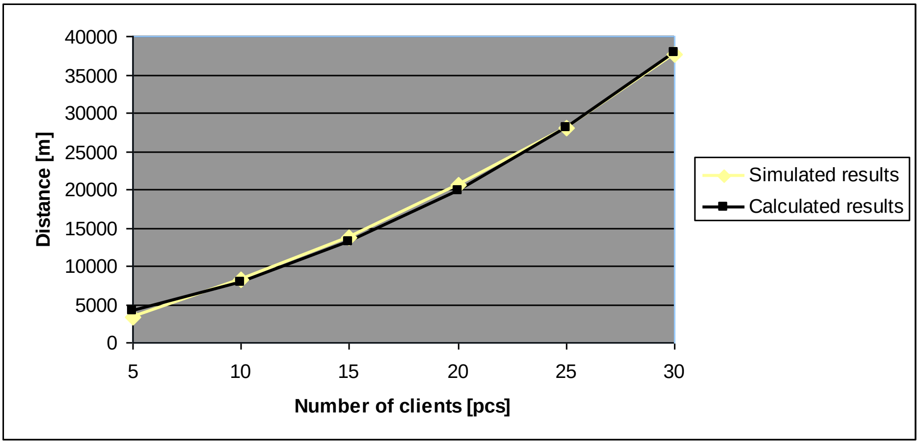

Figure 6. Simulated and calculated distance taken during material handling

The total costs are the sum of delivery costs and depot cost:

$$\Sigma K = \Sigma K_V + \Sigma K_{WH} = \Sigma K_V + K_{fix}^{WH} + K_{fix}^{FL} + K_v^D$$

According to Hirkó the following equation expresses the total delivery costs

$$\Sigma K_V = 0{,}75 \cdot \sqrt{T} \cdot m \cdot k_F^V \cdot \left(\frac{\overline{q}\overline{N}}{g^V} + \sqrt{\overline{N}}\right) + m \cdot \frac{8}{9} \cdot \overline{L_V} \cdot k_F^V \cdot \frac{\overline{q}\overline{N}}{g^V} + K_{fix}^{WH} + n_{FL} \cdot k_{fix}^{FL} + d_0(60 + 10m + m^2) \cdot k_D$$

5. Conclusion

Applications used for vehicle routing simulation are also capable of modeling warehouse processes; by introducing some simplifications and using simulation the total distance and productive time need can be declared. After analyzing the total warehousing costs, three main cost branches can be distinguished: fix warehouse, fix forklift and wage and distance dependent costs. All of these costs have dependence on client number, these correlations were revealed. With the help of former scientific results, we made up a solution to determine client number dependant total costs.

References

[1] Hirkó, B.: *Outsourcing Distribution to a Third Party Logistics Provider Relying Upon Cost Savings Criteria*, Acta Technica Jaurinensis Series Logistica, Győr (2008)

[2] Bookbinder, J.H., Higginson, J.K.: *Probabilistic modelling of freight consolidation by private carriage*, Transportation Research Part E 38 (2002) pp. 305-318

[3] Campbell, J. F.: *Freight consolidation and routing with transportation economies of scale*, School of Business Administration, University of Missouri-St. Louis (1989)
[4] Daganzo, C. F.: *Shipment composition enhancement at a consolidation center, Institute of Transportation Studies*, University of California, Berkeley (1986)
[5] Goddard, L.: *Outsourcing Logistics - The latest trends in using 3PL providers*, Outsourcing Logistics 2005: Best Practice for Managing 3PL Relationships, Hyatt Regency McCormick Place, Chicago, IL (2005)
[6] Griffiths, D.: *Theory & Practice of Outsourcing*, Kudos Information Ltd.
[7] Hall, R. W.: *Comparison of strategies for routing shipments through transportation terminals*, Transportation Research Department, General Motors Research Laboratories, Warren (2002)
[8] Hirkó, B., Németh, P.: *Áruelosztási feladatok stratégiai tervezése*, Logisztikai Évkönyv, MLE (2005)
[9] Hirkó, B.: *Kvázi optimális depószám meghatározása egyszerű kétlépcsős elosztási hálózatban*, Tudományos konferencia, Győr (2007)
[10] Hirkó, B.: *Elosztási logisztika,* Universitas-Győr Kht. (2006)
[11] Hyun Jeung Ko, Chang Seong Ko, Taioun Kim: *A hybrid optimization/simulation approach for a distribution network design of 3PLS*, Computers & Industrial Engineering 50 (2006) pp. 440-449
[12] Jaafar, H. S., Rafiq, M.: *Logistics outsourcing practices in the UK: a survey*, International Journal of Logistics: Research and Applications, Vol.8.No.4 (2005) pp. 299-312
[13] Jonah, C.: *An evaluation of freight consolidation policies in global third party logistics*, The International Journal of Management Science (2002)
[14] Hartványi, T., Nagy, Z.: *Agility in Supply Chains*, Acta Technica Jaurinensis Series Logistica Vol. 1.No.2 (2008) pp. 315-323
[15] Laarhoven, P., Berglund M., Peters, M.: *Third-Party Logistics in Europe-Five Years Later*, International Journal of Physical Distribution & Logistics Management, 30 (5) (2000) pp. 425-442
[16] Sohal, A. S., Millen R., Moss, S.: *"A comparison of the use of third-party logistics services by Australian firms between 1995 and 1999"*, International Journal of Physical Distribution and Logistics Management, Vol.32.No.½ (2002) pp. 59-68
[17] Sventekova, E.: *Outsourcing in transportation*. Mechanics Transport, 3, Academic Journal, Zilina (2007)
[18] Tho Le-Duc.: *Design and Control of Efficient Order Picking Processes*, Thesis to obtain the degree of Doctor from the Erasmus University Rotterdam (2005)
[19] Wei Shi Lim: *A lemons market? An incentive scheme to induce truth-telling in third party logistics providers*, European Journal of Operational Research 125 (2000) pp. 519±525
[20] Bakó, A., Hartványi T., Szűts, I.: *Transportation Network Realization with an Optimization Method*, 4th International Symposium on Computational Intel-ligence and Intelligent Informatics ISCIII (2009) pp. 81-84